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Favro et al.

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(54) **WATERTIGHT FLEXIBLE CONNECTOR**

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(52) **U.S. Cl.** **439/499**
(58) **Field of Search** 439/499, 587, 439/364, 589, 595, 404, 498, 493

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,999,826	A	*	12/1976	Yurtin	439/495
4,526,432	A	*	7/1985	Cronin et al.	439/320
4,740,867	A	*	4/1988	Roberts et al.	361/749
4,950,170	A	*	8/1990	Miller, Jr.	439/74
5,194,010	A	*	3/1993	Dambach et al.	439/79
6,007,377	A	*	12/1999	Cook	439/587
6,039,596	A	*	3/2000	Whiteman et al.	439/404
6,334,250	B1	*	1/2002	Maeda et al.	29/857
6,364,695	B1	*	4/2002	Watanabe	439/498

* cited by examiner

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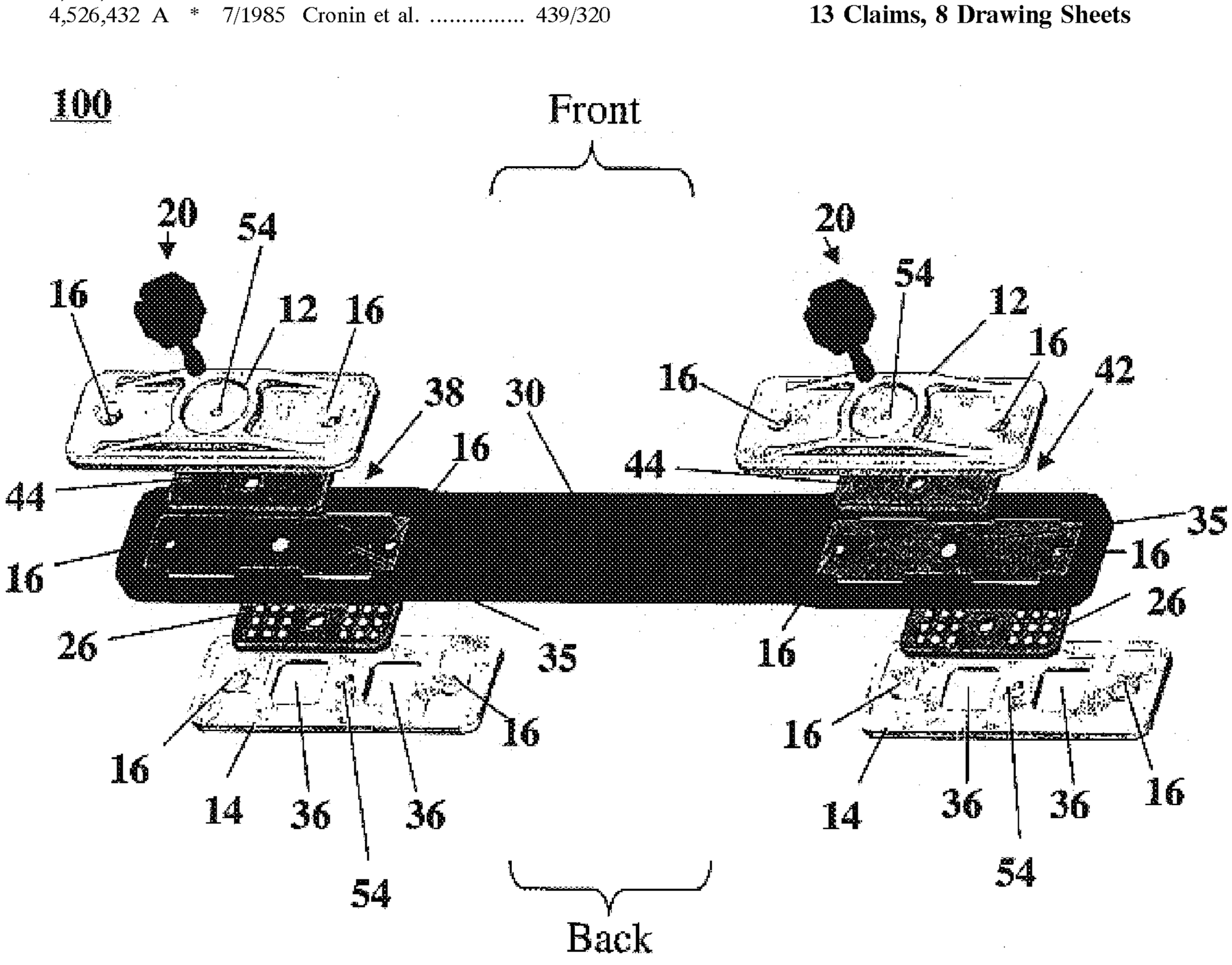
(57) **ABSTRACT**

A watertight connector assembly includes a flat, flexible electrical cable completely encased in an elastomer coating, except at predetermined access openings configured to provide access to the cable. The access openings are defined by O-ring type seals formed in the coating on the surfaces of the cable near each end of the cable. Strain reliefs are positioned within the O-ring type seals. Electrical connectors are positioned within the access openings and configured to provide electrical coupling to the cable and to an external device. Compression pads are positioned adjacent the cable opposite the side of the cable having the electrical connector positioned adjacent thereto. This connector assembly is capable of withstanding harsh environments in compliance with environmental and vibration military specifications.

13 Claims, 8 Drawing Sheets



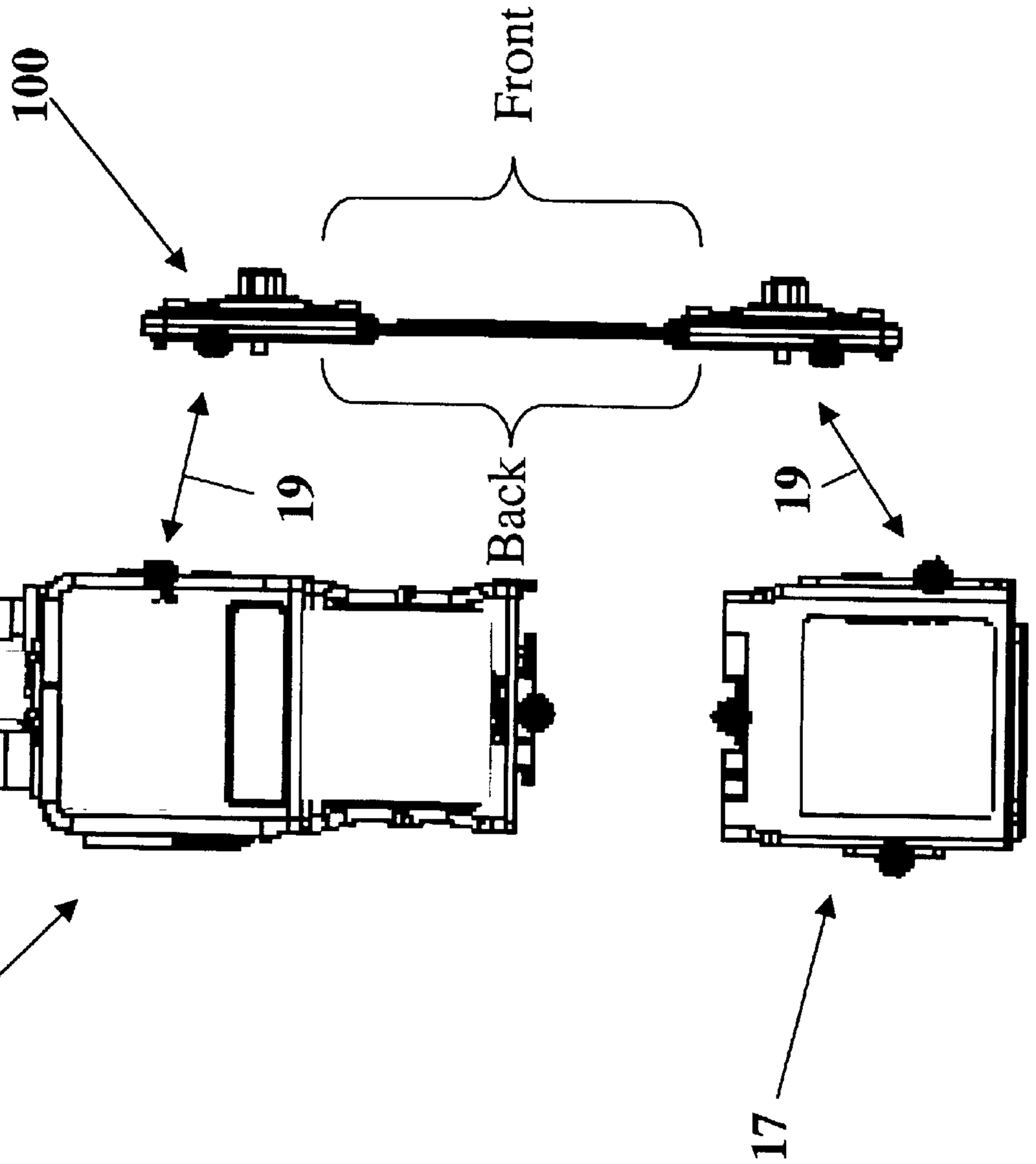


FIGURE 1

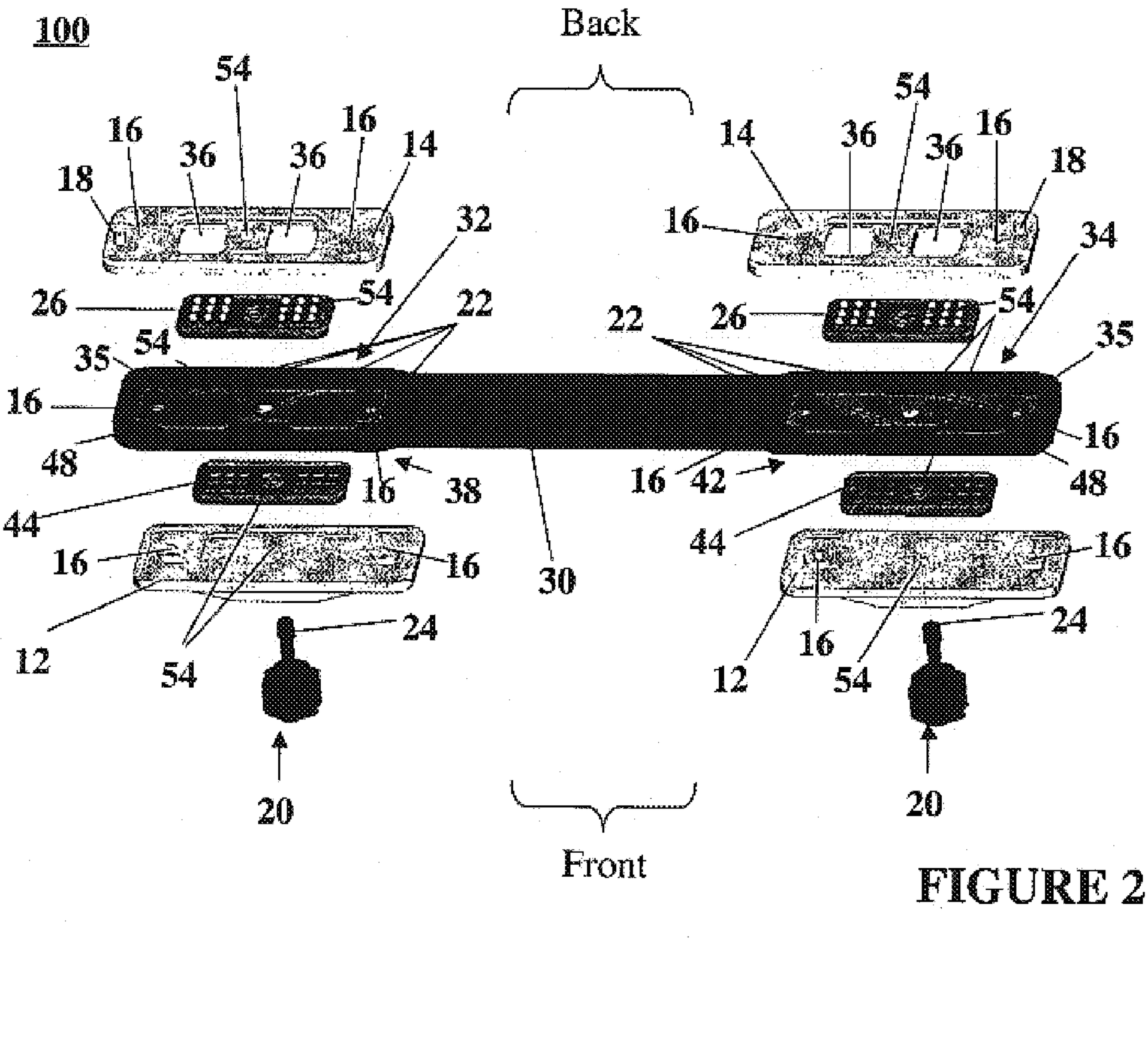

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FIGURE 2

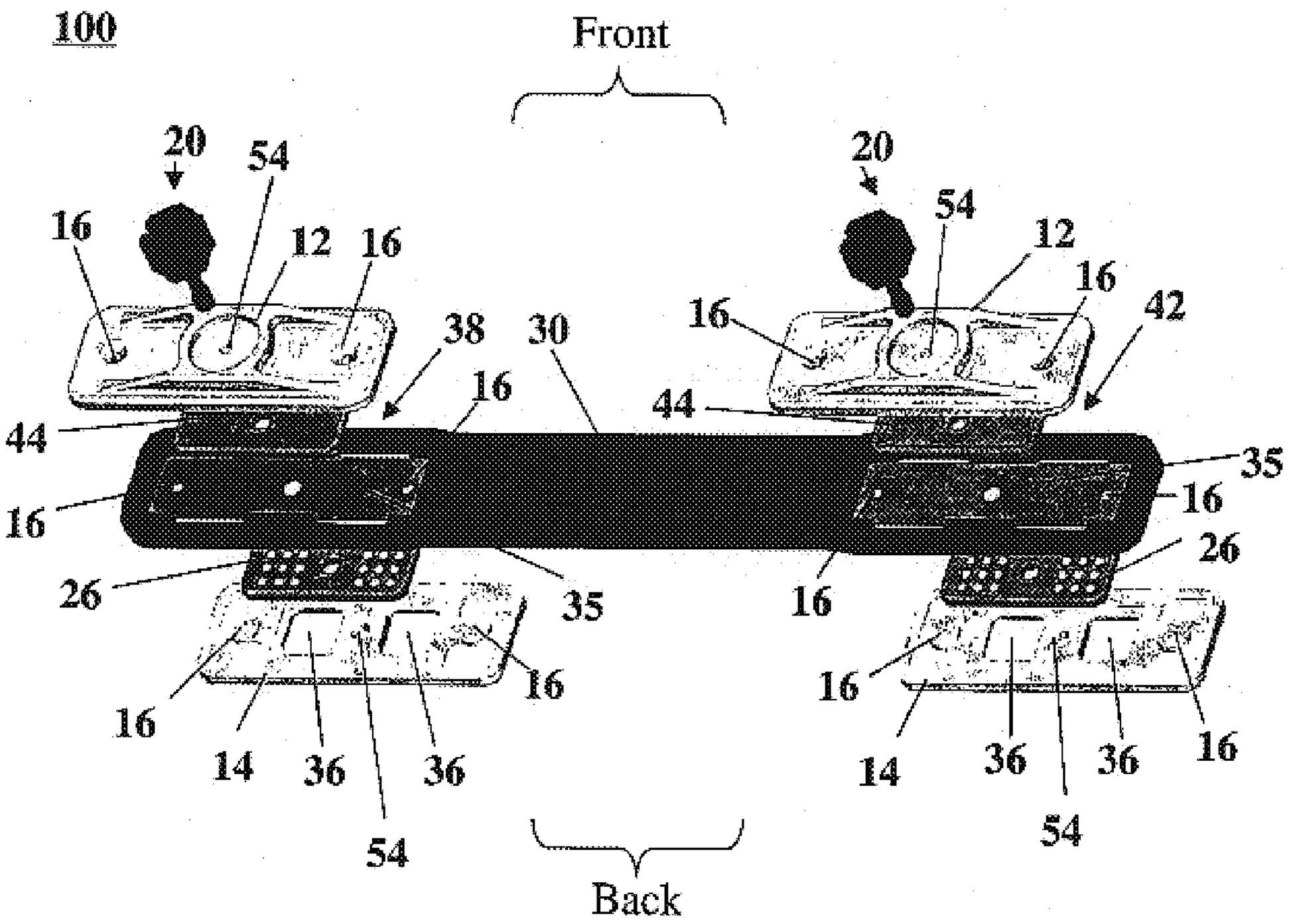
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FIGURE 3

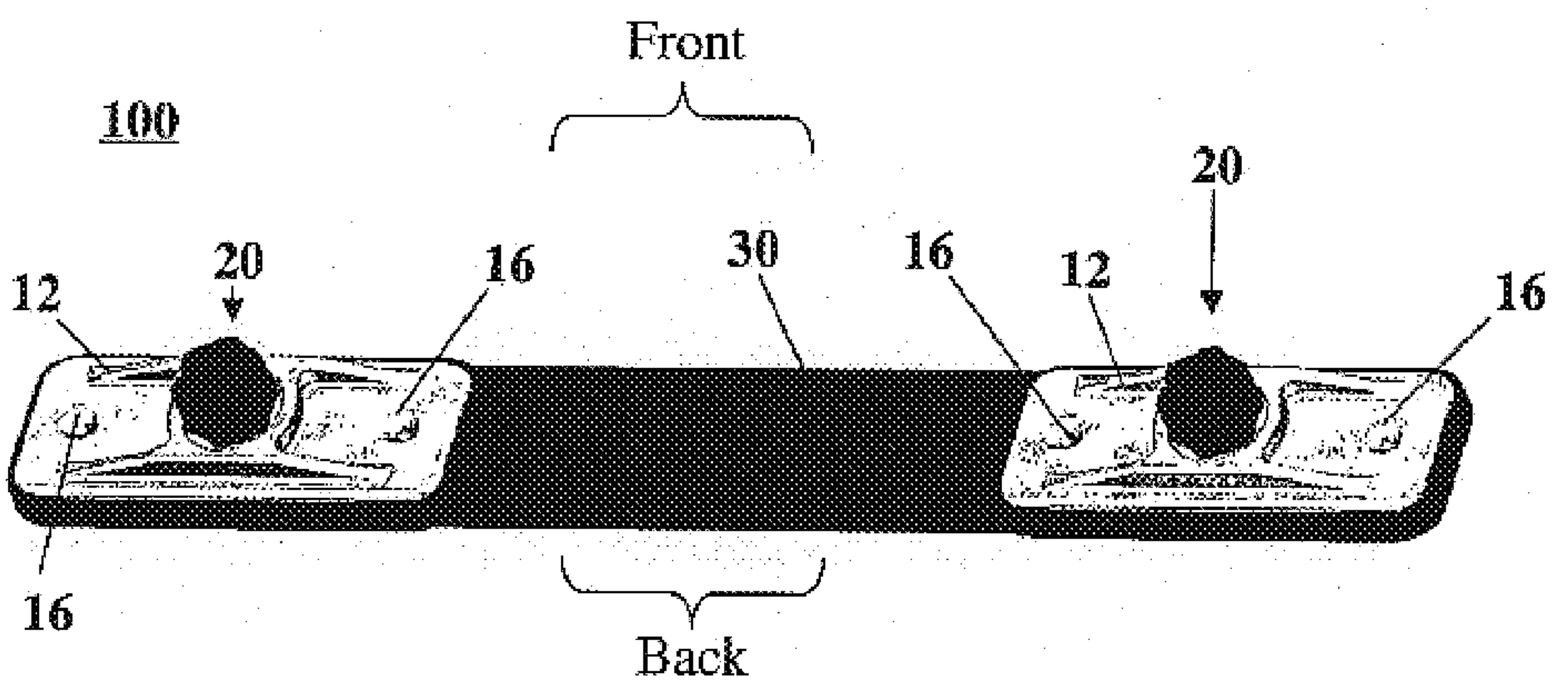


FIGURE 4

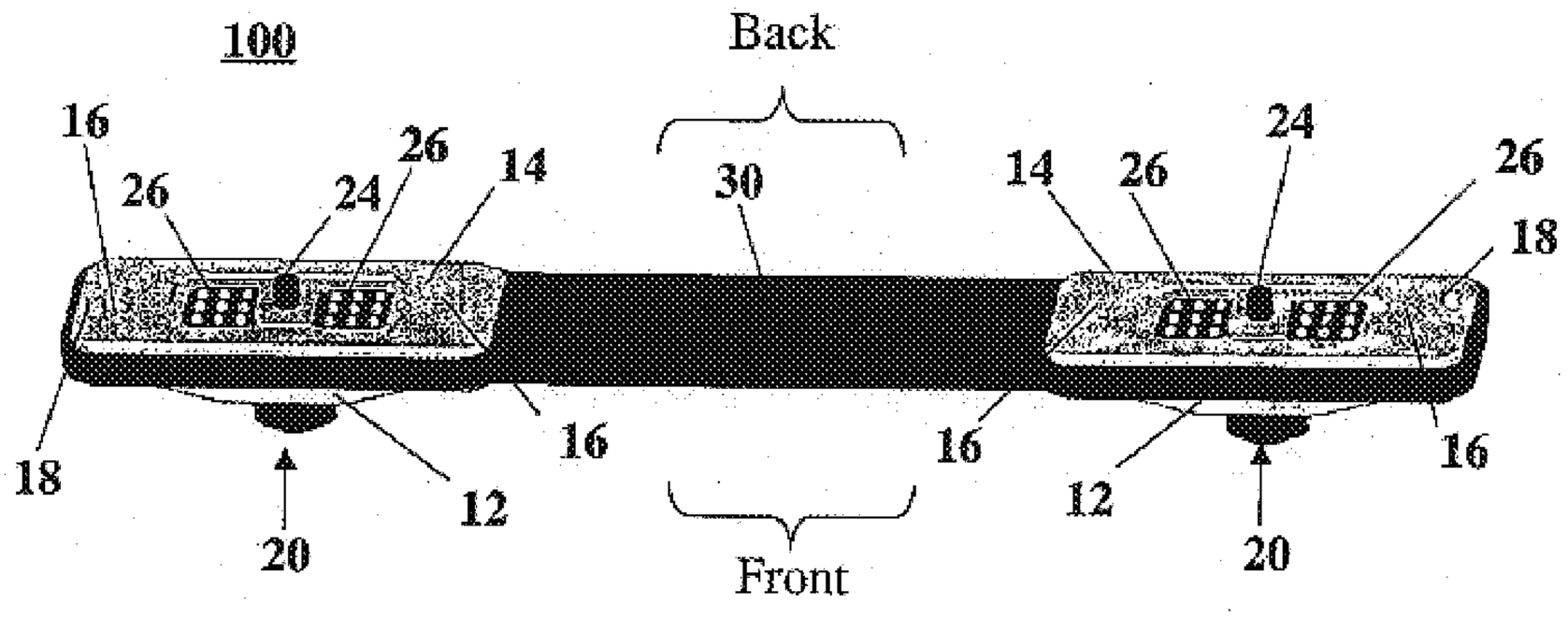


FIGURE 5

FIGURE 6A

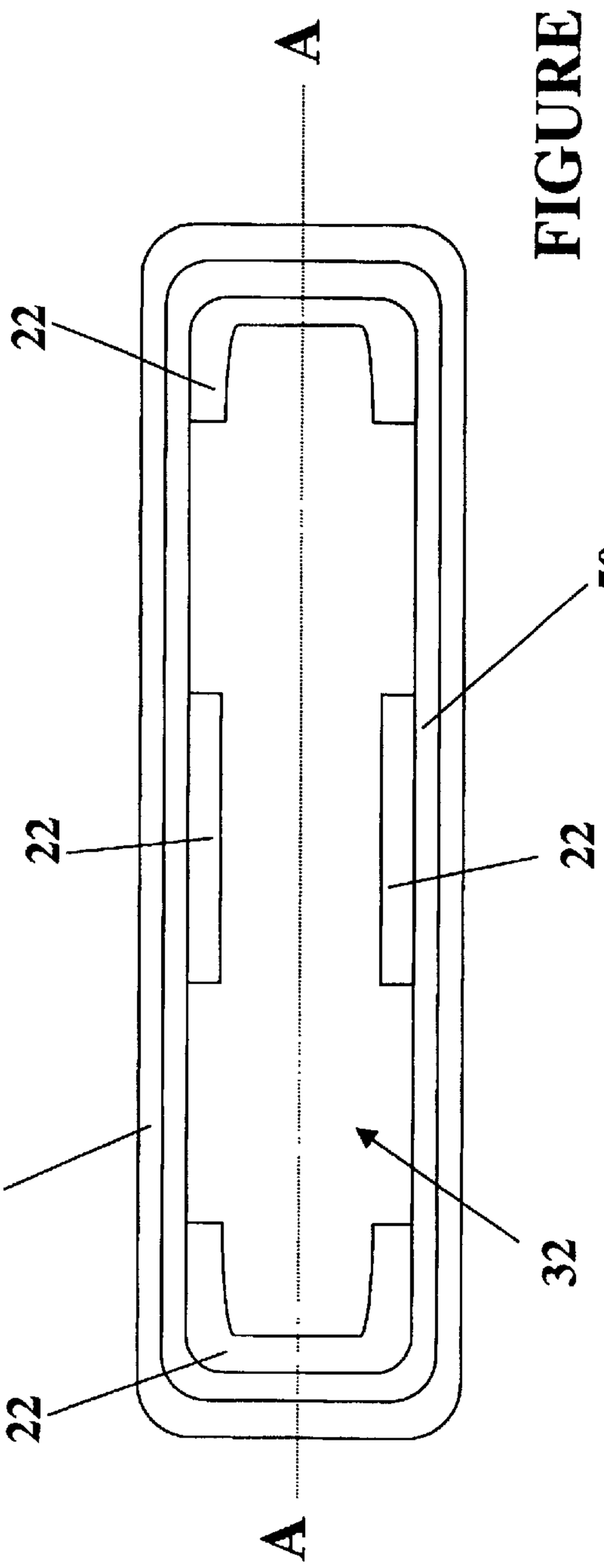
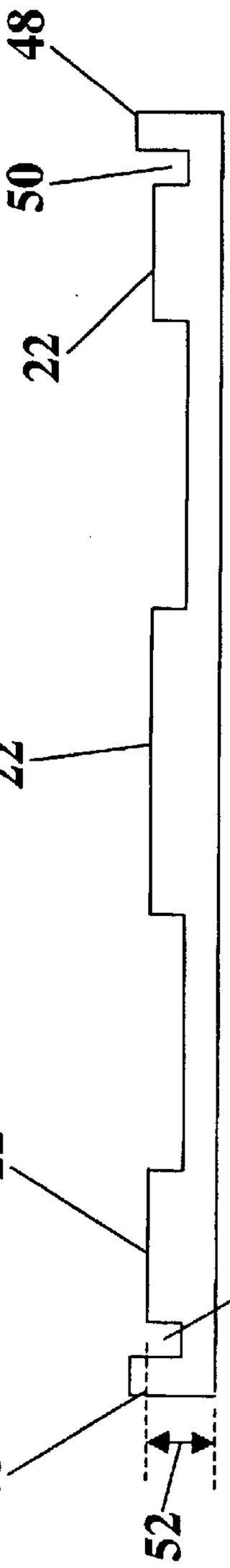


FIGURE 6B



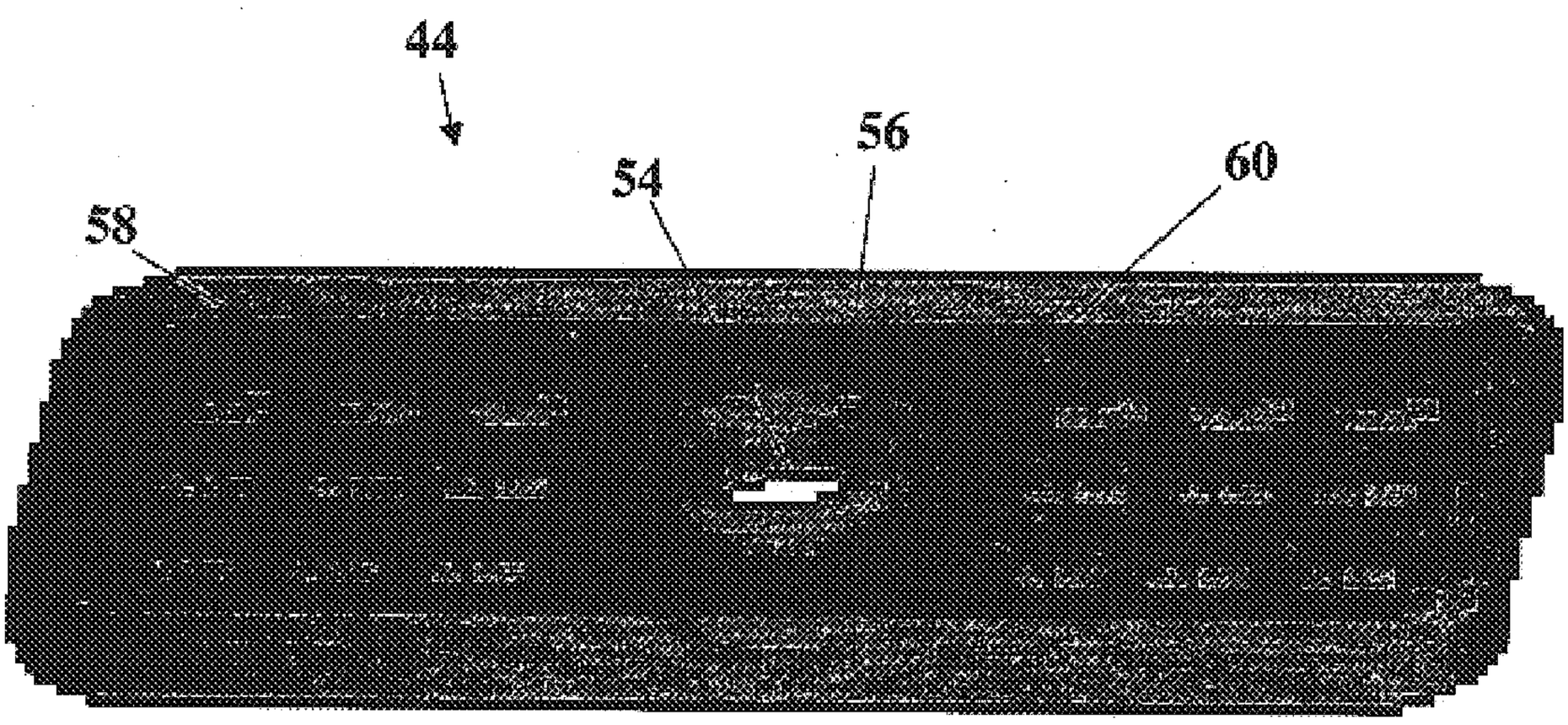


FIGURE 7

FIGURE 8A

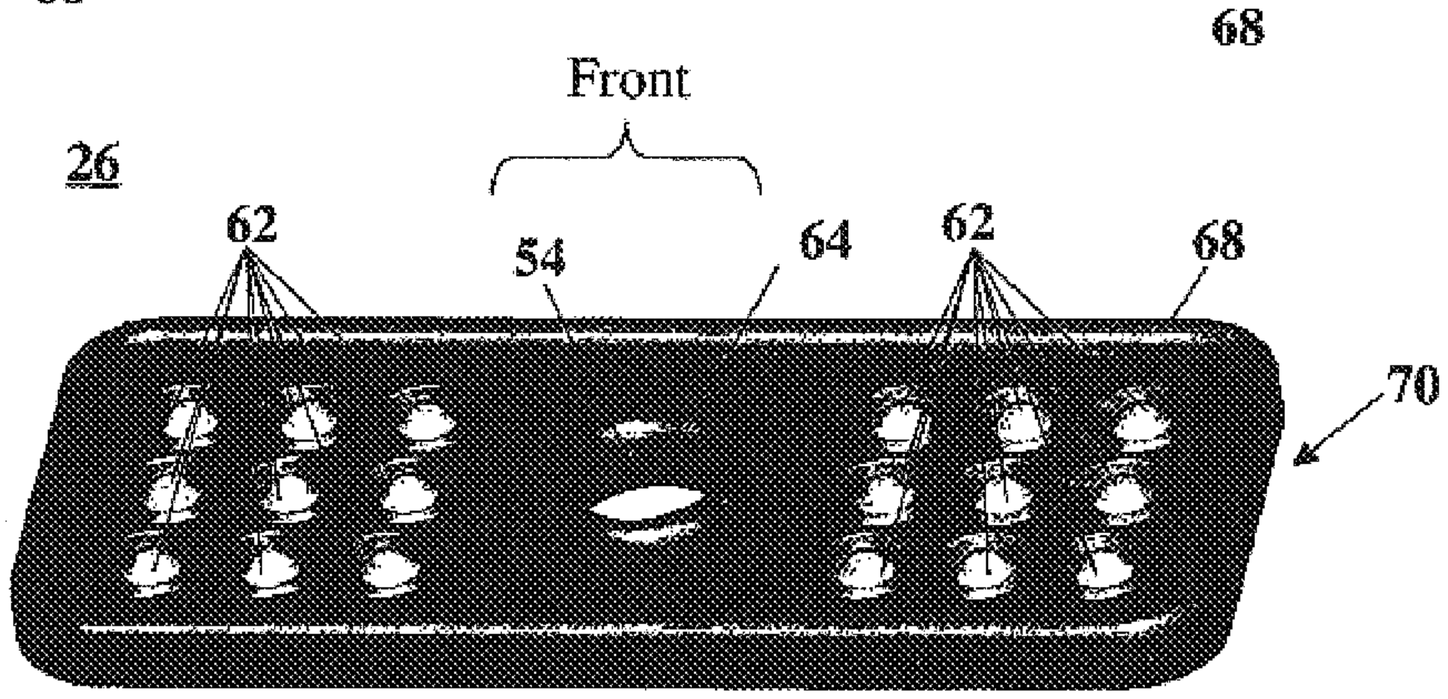
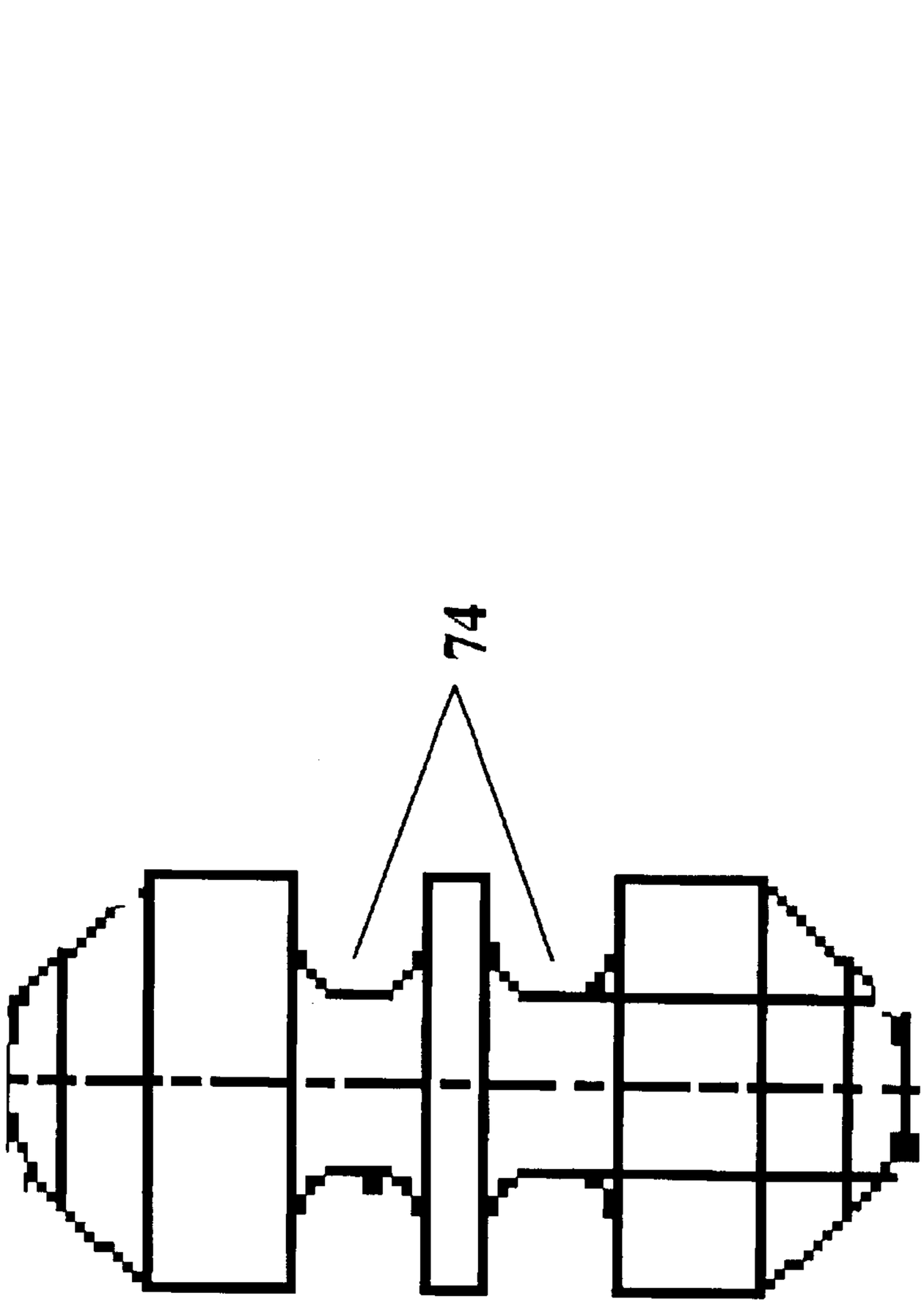


FIGURE 8B

FIG 9



WATERTIGHT FLEXIBLE CONNECTOR

BACKGROUND

The present invention is generally related to radios, and more specifically related to software-defined radios. Electronic equipment used in military applications, such as hand held radios for example, is often subjected to harsh vibration and environmental conditions. Such conditions include extreme temperature fluctuations, excessive moisture, and excessive vibration due to motion of a vehicle or handling of the equipment. These conditions can adversely affect the performance of the equipment. For example, moisture can cause short circuits and corrosion. Temperature variations can cause components to shrink and expand resulting in electrical circuits becoming disconnected or causing intermittent open circuits. Vibration can also cause disconnected circuits or components to fail.

To ensure proper operation of this electronic equipment, components within the electronic equipment must be designed to withstand harsh vibration and environmental conditions. It is often advantageous if the components are small, light weight, and easily configured to fit within the contours of the equipment. Such components typically include various electronic circuits having electrical connectors. Furthermore, it may be desirable to electrically couple a circuit in a first component with a circuit in a second component where the first and second components comprise separate watertight containers. Thus a need exists for a watertight electrical connector capable of withstanding the above-described harsh conditions. The electrical coupling can be achieved via a flexible watertight electrical connector assembly that is capable of electrically connecting at one end one or more circuits in the first component and electrically connecting at the other end to one or more circuits in the second component while maintaining the watertight integrity of the first and second components. This type of flexible watertight electrical coupling is particularly applicable to hand held military radios.

A flexible watertight connector assembly includes a flexible cable encased in an elastomer coating defining a plurality of openings, each opening configured to provide access to the cable. The connector assembly includes at least one electrical connector, each one of the connectors positioned adjacent the cable within a respective one of the plurality of openings. Each electrical connector is configured to be electrically coupled to the cable. The connector assembly also includes at least one pair of covers comprising a first type cover and a second type cover. Each cover is positioned adjacent a respective one of the plurality of openings. Each cover is configured to form a watertight seal with the elastomer coating defining a respective opening. Each first type cover is configured to cover an opening having an electrical connector positioned therein, and each first type cover and a respective electrical connector are configured to form a watertight seal.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. **1** is an illustration of a watertight connector assembly in accordance with the present invention used to couple a handheld radio and a powerblock assembly;

FIG. **2** is an expanded view of the connector assembly showing the back side up;

FIG. **3** is another expanded view of the connector assembly showing the front side up;

FIG. **4** is an illustration of an assembled connector assembly in accordance with the present invention showing the front side up;

FIG. **5** is another illustration of an assembled connector assembly showing the back side up;

FIG. **6**A is a planar view of an access opening formed in an elastomer coating in accordance with an embodiment of the present invention, illustrating strain reliefs, raised edge, and the recessed groove;

FIG. **6**B is a cross-sectional view of the access opening shown in FIG. **6**A;

FIG. **7** is an illustration of a compression pad in accordance with an embodiment of the present invention;

FIG. **8**A is an illustration a back view of an electrical connector in accordance with an embodiment of the present invention;

FIG. **8**B is an illustration a front view the electrical connector shown in FIG. **8**A; and

FIG. **9** is a cross-sectional view of an embodiment of an electrical contact in accordance with an embodiment of the present invention.

DETAILED DESCRIPTIONS

One embodiment of a watertight flexible electrical connector assembly, as described in more detail herein, includes a flat flexible electrical cable encased in an elastomer coating. The coating completely encases the cable except for a predetermined number of access openings configured to provide access to the cable. The access openings are defined by O-ring type seals formed in the coating on the surfaces of the cable near each end of the cable. When assembled, the seals mate with front and rear covers to form a watertight seal for preventing intrusion of water into the connector assembly and to provide vibration absorption. The coating includes strain reliefs positioned within the O-ring type seals (e.g., to provide strain relief from handling of the connector assembly and excessive vibration). The assembly also includes electrical connectors positioned within the access openings and configured to provide electrical coupling to the cable and to an external device (i.e., external to the connector assembly). The electrical connectors include an array of electrical contacts formed in an elastomer base. The elastomer base is configured to provide watertight integrity around the individual electrical contacts, to provide watertight integrity with the mating surfaces of the electrical connector and its respective cover, and to provide vibration absorption. The connector assembly includes compression pads positioned adjacent the cable opposite the side of the cable having the electrical connector positioned adjacent thereto. The compression pads provide vibration absorption and watertight integrity, and ensure electrical coupling between the electrical contacts and the cable. This connector assembly is configured to withstand harsh environments in compliance with environmental and vibration military specifications.

In this description, relative terms such as "horizontal," "vertical," "up," "down," "top," "bottom," "back," and "front" as well as derivatives thereof (e.g., "horizontally," "downwardly," "upwardly," etc.) should be construed to refer to the orientation as then described or as shown in the drawing figure under discussion. These relative terms are for convenience of description and normally are not intended to require a particular orientation. Terms including "inwardly" versus "outwardly," "longitudinal" versus "lateral" and the like are to be interpreted relative to one another or relative

to an axis of elongation, or an axis or center of rotation, as appropriate. Terms concerning attachments, coupling and the like, such as "connected" and "interconnected," refer to a relationship wherein structures are secured or attached to one another either directly or indirectly through intervening structures, as well as both movable or rigid attachments or relationships, unless expressly described otherwise.

Referring now to FIG. **1**, there is shown a connector assembly **100** in accordance with the present invention used to couple a handheld radio **15** and a powerblock assembly **17**. As shown in FIG. **1**, the connector assembly **100** is in an assembled configuration. The depiction of handheld radio **15** being coupled to powerblock assembly **17** by the connector assembly **100** is exemplary. The connector assembly **100** may be used to couple any appropriate external devices. The arrows **19** indicate locations at which the connector assembly **100** may be connected to the handheld radio **15** and the powerblock assembly **17**. The connector assembly **100** provides means for electrical signals to be coupled between devices (e.g., the powerblock assembly **17** and the handheld radio **15**) coupled to the connector assembly **100**. The designation of front side and back side of the connector assembly **100**, as shown in FIG. **1**, will be used throughout this description.

FIGS. **2** and **3** are expanded views of the connector assembly **100** showing back side up and front side up, respectively. FIGS. **4** and **5** are assembled views of the connector assembly **100** showing front side up and back side up, respectively. Referring to FIGS. **2**, **3**, **4**, and **5**, the connector assembly **100** includes front covers **12**, back covers **14**, electrical connectors **26**, compression pads **44**, external device fasteners **20** depicted as thumb screws, and a flexible cable **35** encased in an elastomer coating **30**. In one embodiment of the connector assembly **100**, the flexible cable **35** is a flat, flexible cable providing electrical coupling between the ends of the flexible cable **35**. The elastomer coating **30** may comprise any appropriate material providing elastic properties, such as urethane or silicone, for example. The cable **35** is completely encased by the elastomer coating **30** except at predetermined access openings. The elastomer coating **30** defines access openings **32**, **34**, **38**, and **42**. The access openings **32**, **34**, **38**, and **42** are defined by respective raised edges **48**. Raised edges **48** arc in the form of an O-ring type seal surrounding the perimeter of each opening **32**, **34**, **38**, and **42**. In one embodiment, the O-ring type seal is positioned in the bottom of the recessed groove **50** (not shown in Figures), and the raised edge **48** is positioned external to the mounting covers to facilitate the elimination of the gap between respective covers. The access opening **32** and **38** are positioned on opposing back and front sides, respectively, of the connector assembly **100**. The access opening **34** and **42** are positioned on opposing back and front sides, respectively, of the connector assembly **100**. The access openings **32**, **34**, **38**, and **42** provide access to the flexible cable **35**. The locations of the access openings **32**, **34**, **38**, and **42** are exemplary. More or less access opening may be formed. The location of the access openings may also differ from the locations shown in FIG. **2**. For example, a connector assembly in accordance with the present invention may have one end hardwired to an external device and the other end may be detachable. In this configuration, the connector assembly would include two opposing access openings respectively located on the front and back sides of the connector assembly. In another embodiment, a connector assembly in accordance with the present invention may comprise three connection sites (for example, for coupling three external devices to each other). This embodiment would comprise six access openings, configured as three opposing pairs of access openings respectively located on the back and front sides of the connector assembly.

At each end of the connector assembly **100**, respective front covers **12** and back covers **14** are fastened together by an appropriate assembly fastener (assembly fastener now shown) inserted into fastening openings **16**. Each of the front covers **12**, the back covers **14**, and the cable **35** define a respective pair of fastening openings **16**. The number of fastening openings is exemplary and may be increased or decreased. Examples of appropriate assembly fasteners to be inserted into fastening openings **16** include threaded fasteners, such as Phillips head and flat head screws, riveted fasteners, or a combination thereof. Each back cover **14** defines at least one back cover access opening **36**. As described in more detail below, each back cover access opening **36** is configured to conformably mate with a respective electrical connector **26**.

In an alternate embodiment, the front covers **12** do not comprise fastening openings **16**. Rather, the front cover **12** comprises a boss like structure protruding from the surface of the front cover **12** adjacent the cable **35** positioned in the where the fastening openings **16** would be positioned. The boss like structure does not form an opening. In this embodiment, a fastener is inserted through the fastener opening **16** on the back cover **14** and threadabley received by the boss like structure. The boss like structure facilitated the prevention of water intrusion into the cable assembly **100**.

The external device fasteners **20**, depicted as thumbscrews facilitate the fastening of the connector assembly **100** to an external device. Each thumbscrew **20** comprises a threaded portion **24**, which is inserted through the central openings **54** and threadably attached to a respective external device. In one embodiment, the central opening **54** of each front cover **12** comprises threads for receiving the threaded portion **24** of a thumbscrew **20**, and for preventing the thumbscrew **20** from becoming inadvertently detached from the connector assembly **100**. In this embodiment, the remainder of the central openings **54** (e.g., defined by compression pad **44**, cable **35**, electrical connector **26**, and back cover **14**) do not contain threads, allowing the threaded portion **24** of the thumbscrew **20** to slide through these remainder of central openings. In one embodiment, the thumbscrew is recessed on the underside of the head to accommodate an O-ring type seal to provide a water resistant seal around the central opening **54**. Guide pins **18** facilitate the positioning of each end of the connector assembly **100** on each respective external device and help prevent rotation of the connector assembly **100** when it is attached to a respective external device. In one embodiment, a seal (e.g., O-ring type seal) is positioned around the perimeter of each back cover **14** on the surface of the back cover that mates with the external device. This seal facilitates the provision of watertight integrity between the connector assembly **100** and an external device. As previously described, in one embodiment, an O-ring type seal is positioned in the bottom of the recessed groove **50**, and the raised edge **48** is positioned external to the mounting covers to facilitate the elimination of the gap between respective covers.

FIG. **6**A is a planar view of the access opening **32** illustrating strain reliefs **22**, raised edge **48**, and recessed groove **50**. FIG. **6**B is a cross-sectional view of the access opening **32** at line A—A. Each access opening **32**, **34**, **38**, and **42** is formed by a raised edge **22** in the elastomer coating **30** and has positioned therein strain reliefs **22**. Strain reliefs

22 provide relief from strain placed on the connector assembly from handling by a user and from vibration. Recess groove **50** is formed between raised edge **48** and strain reliefs **22**. The recessed groove **50** is configured to receive a protruding edge of a respective cover (e.g., back cover **14** for access opening **38**) when the connector assembly **100** is assembled. The strain reliefs **22** are raised to a level between the recessed groove **50** and the raised edge **48**, as indicated by arrow **52** in FIG. **3**B. As described in greater detail below, when the back cover **14** is positioned over the access opening **32**, the assembled connector assembly **100** provides a water tight seal formed by the mating of the raised edge **48** with an inner surface of the back cover **14** and the mating of the recessed groove **50** with the protruding edge of the back cover **14**. Similarly, the connector assembly **100** provides a watertight seal formed by the mating of each access opening with its respective cover.

FIG. **7** is an illustration of a compression pad **44**. Each compression pad **44** defines a central opening **54** and comprises a compression pad raised edge **58**, a central opening raised edge **56**, and a recessed region **60**. The compression pad **44** is formed of a material having elastic properties, such as the elastomer materials urethane or silicone, for example. The compression pad raised edge **58** is formed around the perimeter of the compression pad **44**. The central opening raised edge **56** if formed around the perimeter of the central opening **54**. The raised edges **56**, **58**, are formed on both sides of the compression pad **44**. Each of the raised edges **56**, **58**, facilitate the formation of a watertight seal when the connector assembly **100** is assembled. When the connector assembly **100** is assembled, the compression pad raised edge **58** on one side of the compression pad **44** mates with a respective front cover **12** to form a watertight seal therebetween. The compression pad raised edge **58** on the other side of the compression pad **44** mates with the flexible cable **35** also to provide a watertight seal therebetween. Similarly, the central opening raised edge **56** on one side of the compression pad **44** mates with a respective front cover **12** at the perimeter of the front cover's central opening **54** to form a watertight seal therebetween. The central opening raised edge **56** on the other side of the compression pad **44** mates with the flexible cable **35** also to provide a watertight seal therebetween. Furthermore, in one embodiment, raised pad like portions on the front and back surfaces of the compression pad **44** provide a spring like force against the flexible cable **35** to facilitate the electrical connection between the flexible cable **35** and a respective electrical connector **26**. The recessed region **60** may be formed to include appropriate surface contours to also facilitate an electrical connection between a respective electrical connector **26** and the flexible cable **35**.

FIGS. **8**A and **8**B illustrate a back view and a front view, respectively, of the electrical connector **26**. Each electrical connector **26** comprises a base portion **70** defining a respective central opening **54**. The base portion **70** is formed of a material having elastic properties, such as the elastomer materials urethane or silicone, for example. The base portion **70** has positioned therein, a plurality of electrical contacts **62**. The base portion **70** is formed to include an electrical connector raised edge **68**, a base central opening raised edge **64**, and a raised portion **66**. The base portion raised edge **68** is formed around the perimeter of the base portion **70**. The base central opening raised edge **64** is formed around the perimeter of the central opening **54**. The raised edges **64**, **68**, are formed on both sides (front and back) of the base portion **70**. Each of the raised edges **64**, **68**, facilitate the formation of a watertight seal when the connector assembly **100** is assembled. When the connector assembly **100** is assembled, the base portion raised edge **68** on the back side of the electrical connector **26** mates with a respective back cover **14** to form a watertight seal therebetween. The raised portion **66** is configured to conform to the shape of the back cover access openings **36**. The base portion raised edge **68** on the front side of the electrical connector **26** mates with the flexible cable **35** also to provide a watertight seal therebetween. Similarly, the base central opening raised edge **64** on the back side of the base portion **70** mates with a respective back cover **14** at the perimeter of the back cover's central opening **54** to form a watertight seal therebetween. The base central opening raised edge **64** on the front side of the electrical connector **26** mates with the flexible cable **35** also to provide a watertight seal therebetween. In an alternate embodiment, the base portion **70** comprises raised portions **66** on both the front and back sides of the electrical connector **26**.

FIG. **9** is a cross-sectional view of an electrical contact **62**. The electrical connector **62** is configured to include circumferentially recessed regions **74**. When the electrical contact **62** is positioned within the base portion **70**, the elastomer material of the base portion **70** is in contact with the surface of the circumferentially recessed regions **74**. This configuration facilitates retention of the electrical contacts **62** within the base portion **70** of the electrical connector **26**. This configuration also prevents water from penetrating through the base portion **70** along the surface of the electrical contact **62**, thus providing a watertight seal between the back and front side of the electrical connector **26**. Furthermore, the elastic properties of the material used to form the base portion **70** in conjunction with the shape of the electrical contacts **62**, allows each electrical contact **62** to move independently. This independent movement facilitates the retention of the electrical coupling between the electrical contacts **62** and the flexible cable **35** while the connector assembly **100** is subject to various types of kinetic energy, such as vibration and handling the connector assembly **100** (e.g., using the connector assembly **100** as a handle to carry the handheld radio and powerblock assembly).

A connector assembly as described herein provides a low profile, watertight cable assembly that is capable of withstanding harsh environments to the point of meeting MIL-SPEC standards. The coupling between the electrical contacts **62** and the flexible cable **35** is a result of a pressure contact. No soldering is required to form electrical connections. The compression pad **44** absorbs vibration and other types of kinetic energy, thus allowing the electrical contacts **62** to move while electrical contact is maintained between the electrical contacts **62** and the flexible cable **35**. The electrical connector **26** provides watertight integrity via the shape (e.g., hourglass cross section) of the electrical contacts **62** and the conformably shaped elastomer material in the base portion **70** of the electrical connector **26**. Furthermore, the shape of the electrical contacts **62** in conjunction with the shape of the base portion **70** (e.g., raised portion **66**) allow independent movement of each electrical contact **62** and prevents the electrical contacts **62** from electrically shorting to each other or to the back cover **14**.

Although illustrated and described herein with reference to certain specific embodiments, the watertight connector assembly and apparatus as described herein is nevertheless not intended to be limited to the details shown. Rather, various modifications may be made in the details within the scope and range of equivalents of the claims and without departing from the spirit of the invention.

What is claimed is:

1. A flexible watertight connector assembly comprising:

a flexible cable encased in an elastomer coating defining a plurality of openings, each opening configured to provide access to said cable;

at least one electrical connector, each one of said at least one electrical connector positioned adjacent said cable within a respective one of said plurality of openings, each electrical connector configured to be electrically coupled to said cable; and

at least one pair of covers comprising a first type cover and a second type cover, each cover positioned adjacent a respective one of said plurality of openings, each cover configured to form a watertight seal with said elastomer coating defining a respective opening, wherein:

each first type cover is configured to cover an opening having an electrical connector positioned therein; and

each first type cover and a respective electrical connector are configured to form a watertight seal.

2. A connector assembly in accordance with claim **1**, further comprising:

at least one compression pad positioned adjacent an opposite side of said cable having a respective electrical connector positioned adjacent thereto, and positioned between said cable and a respective second type cover.

3. A connector assembly in accordance with claim **2**, each compression pad comprising a compression pad raised edge formed on a perimeter of said compression pad, wherein:

said compression pad raised edge is configured to form a watertight seal with said cable and a respective second type cover.

4. A connector assembly in accordance with claim **1**, said elastomer coating comprising:

a plurality of coating raised edges, each one of said plurality of coating raised edges surrounding a respective one of said plurality of openings, wherein:

each coating raised edge defines each respective opening; and

each coating raised edge is configured to form a watertight seal with each respective cover.

5. A connector assembly in accordance with claim **4**, further comprising:

a plurality of strain reliefs positioned within each of said plurality of openings adjacent said plurality of coating raised edges.

6. A connector assembly in accordance with claim **1**, further comprising a plurality of external device fasteners for fastening said assembly to an external device, wherein:

fastening openings for receiving a respective external device fastener are defined by respective covers, by a respective electrical connector, and by a respective portion of said cable within a respective access opening; and

said fastening openings are aligned to receive said respective fastener when said connector assembly is assembled.

7. A connector assembly in accordance claim **6**, wherein:

said fastener is a threaded fastener; and

at least one of said fastener openings comprises threads for receiving said threaded fastener.

8. A connector assembly in accordance claim **1**, each first type cover defining at least one cover access opening, each electrical connector comprising:

a molded elastomer base;

a plurality of electrically conductive contacts positioned within at least one raised portion of said base, said plurality of contacts configured to be electrically coupled to said cable, wherein:

each raised portion is configured to conformably mate with a respective cover access opening in a respective first type cover; and

a raised edge formed on a perimeter of said base is configured to form a watertight seal with said cable and a respective first type cover.

9. A connector assembly in accordance with claim **8**, each electrical contact comprising at least one indentation formed around a circumference of said electrical contact, wherein a surface of each indentation and said molded elastomer base form a watertight seal.

10. A connector assembly in accordance with claim **1**, further comprising:

at least one elastomer seal configured to provide a watertight seal when said connector assembly is coupled to an external device, each of said at least one elastomer seal positioned on a perimeter of each respective first type cover.

11. A connector assembly in accordance with claim **1**, wherein each first type cover comprises at least one guide pin for aligning said first type cover with an external device.

12. A connector assembly in accordance with claim **1**, further comprising at least one assembly fastener for assembling said connector assembly.

13. A connector assembly in accordance with claim **12**, said assembly fastener further comprising a recessed portion adjacent a head of said assembly fastener, said recessed portion adjacent said head configured to receive an assembly fastener seal for forming a watertight seal between said assembly fastener and a respective second type cover.

* * * * *